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THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

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Summary

This report considers the amount of amplitude modulation which can be permitted to occur on the sound carrier of u.h.f. Standard I television transmissions. Some brief subjective tests have been carried out using domestic receivers, and these show that slight impairment of the sound signal may occur with the amount of intermodulation occurring in existing transmitting amplifiers carrying vision and sound signals simultaneously.

1. Introduction

In a frequency-modulated transmission, it is usual to specify the maximum permissible level of spurious amplitude modulation (a.m.). Such a.m. can arise at a transmitter, from various causes, such as a non-flat frequency transfer characteristic, reflections in the aerial feeder arising from impedance mismatches, and imperfectly-smoothed power supplies. In the case of the f.m. sound channel in a Standard I u.h.f. television transmission, another important source of a.m. occurs if the vision and sound channels pass through a common amplifier, which is normally employed at relay stations. In this case, because of amplifier non-linearity, a.m. arises from cross-modulation from the vision to the sound signal.[1,2,5] The predominant subjective effect on the sound signal is a low-frequency 'buzz' which varies with picture content. Other effects also arise from this cross-modulation. In particular, a 1·57 MHz pattern may occur on the picture, caused by a beat between the sound carrier and the colour subcarrier. However, the present investigation is concerned primarily with the effect of the spurious a.m. on the sound signal, although reference will be made to other effects where appropriate, in order to form a background for assessing the significance of the problem.

The subjective tests were very brief, and a more thorough investigation would be required to establish conclusive results, but they are sufficient to indicate that cross-modulation causing impairment of the sound signal must be carefully considered when specifying the performance of amplifiers common to the vision and sound signals.

2. Spurious phase modulation

In the non-linear process causing intermodulation, the sound carrier may be phase-modulated, as well as amplitude-modulated, by the vision signal. It would be unrealistic to demand a very much better performance with respect to a.m. than with respect to the associated unwanted phase modulation (p.m.) so it is appropriate to estimate the likely amount of p.m.

In the absence of a definite specification of the spurious p.m., it may be noted that a typical value for level-dependent phase distortion of the colour sub-carrier is 3°. It is assumed that a similar figure may apply to the spurious phase variation of the sound carrier.

If m is the modulation index corresponding to a phase variation of ±1·5°,

$$m = \frac{1{\cdot}5}{57{\cdot}3} = 0{\cdot}026$$

Therefore, if the spurious modulation occurs at a frequency of, say, 1 kHz, the corresponding f.m. deviation of 0·026 kHz. This represents a level of −66 dB relative to full 50 kHz deviation. In practice, the spurious modulation will have predominantly a low-frequency (frame) component and its harmonics, so that the effective level of the intermodulation signal will be less than −66 dB.

3. Expected effects of amplitude modulation

It will be assumed that the impairment caused by the cross-modulation to the sound signal can be given as a signal-to-weighted-noise ratio of 65 dB, using a quasi-peak meter and a noise-weighting curve in accordance with C.C.I.T.T. recommendations.[3] It is difficult to assign a precise weighting factor appropriate to the type of noise being considered, but in view of the predominance of low-frequency effects, 5 dB is considered to be reasonable. Therefore the spurious audio output caused by the cross-modulation should not exceed −60 dB, relative to 100% modulation of the wanted signal. This requirement is fulfilled in the case of spurious phase modulation, as discussed in Section 2. The level of a.m. which will produce this amount of spurious output depends on the a.m. suppression ratio of the receiver. This is the ratio of the audio outputs which result from equal percentage modulations of f.m. and a.m. respectively.[4] It is undesirable to depend too much on receiver design in this respect, but on the other hand it is reasonable to expect the receiver to make some contribution to reducing the effect of a.m. No generally-accepted recommended value of the a.m. suppression ratio

exists, but it is suggested that 30 dB could be obtained without undue difficulty. Therefore, if the spurious output is not to exceed −60 dB relative to 100% wanted modulation, the depth of a.m. must be −30 dB, i.e. approx. 3%.

This is a rather stringent specification which may be difficult to meet at relay stations employing klystron amplifiers, and it is worth considering any mitigating factors which may enable the specification to be slackened.

Firstly, the quoted spurious output level of −60 dB may be somewhat too severe a requirement. Bearing in mind, however, that the most prominent effect is likely to be a low-frequency buzz which can be of a rather annoying nature, it is considered that this level is not too low if the sound signal is to be considered to be of a high quality.

Secondly, it may be argued that the quality of the sound accompanying a television picture need not be of quite as high a standard as that demanded for a sound-only transmission. Such an assumption should be treated with great reserve, but nevertheless it would probably be realistic to accept that a level of −57 dB could be accepted, in which case the sound carrier a.m. could become 4·5%.

Thirdly, it should be remembered that inter-carrier sound reception is universally employed in domestic television receivers, and in this case it is almost inevitable that internally-generated cross-modulation between the vision and sound carriers will cause a.m. of the sound carrier, which may well be much greater than that produced by the transmission system.

Finally, it may be pointed out that the degree of intermodulation depends upon the picture content, so that the maximum level of spurious signals will occur for only part of the time.

Bearing in mind all these considerations, it would be expected that 5% a.m. would result in a sufficiently small contribution to the impairment of the sound signal, provided that the receiver has at least 30 dB a.m. suppression.

4. Theoretical prediction of sound carrier amplitude variation

The sound carrier amplitude variation caused by cross-modulation with the vision signal in a klystron amplifier can be calculated[2] with reasonable accuracy.

If K_1 is the input vision carrier voltage at peak white, and K_2 is the input vision carrier voltage at sync. tips, both values being normalised with respect to the input voltage required to produce the saturated power output, the percentage variation in the amplitude of the sound carrier is

$$\left[1 - \frac{J_0(1{\cdot}84\,K_1)}{J_0(1{\cdot}84\,K_2)}\right] \times 100$$

where J_0 signifies the Bessel function of the first kind and zero order. If the values of K_1 and K_2 are chosen to correspond to operating conditions in which the power output at sync. tips is 7 dB below saturation, we find that the amplitude variation is about 7%.

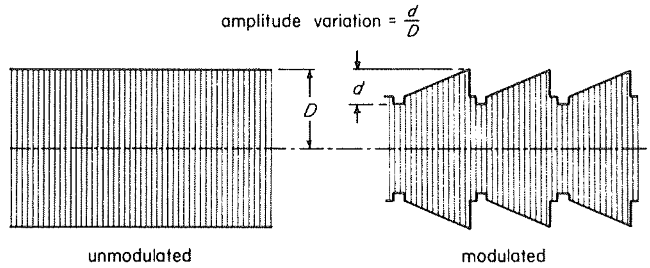

Fig. 1 - Sound carrier envelope

To avoid confusion, it is emphasised that the expression 'amplitude variation' is taken to mean a reduction in sound carrier amplitude due to 'crushing' by the vision carrier, as shown in Fig. 1. For normal sinusoidal a.m., the amplitude increases, as well as decreases, relative to the mean of the envelope, and the modulation depth is defined as the percentage increase or decrease of the amplitude. Thus, the amplitude variation defined in accordance with Fig. 1 is numerically equal to twice the depth of a.m., for shallow depths of modulation. It therefore follows from Section 3 that a 10% amplitude variation of the sound carrier, caused by cross-modulation, may be expected to produce little impairment of the sound signal in a receiver with 30 dB a.m. suppression.

5. Subjective tests on domestic receivers

In order to assess the importance of the sound carrier a.m. on typical domestic receivers, some simple subjective tests were carried out on five different receivers, two of which were colour receivers, and three monochrome.

5.1. Arrangement of equipment

A block diagram of the arrangement is shown in Fig. 2. Referring to this figure, the 6 MHz oscillator was frequency-modulated by tone or speech, to a peak deviation of ±50 kHz, normal 50 μsec pre-emphasis being applied to the audio signal. After frequency-changing to 63 MHz, the sound-modulated carrier could be amplitude-modulated by a full bandwidth vision signal or by an audio-frequency repetitive waveform. Negative a.m. was employed, so that the envelope on sawtooth modulation was inverted, relative to that shown in Fig. 1, but this should not affect the conclusions. After adding the resultant sound signal to a 57 MHz a.m. vision channel the composite signal was frequency-converted to the u.h.f. band.

The amplitude variation (defined in Fig. 1) was measured at v.h.f. on an oscilloscope. The accuracy of the measurement at small variations was therefore somewhat restricted, but it was sufficient for the present purpose.

In all the tests on the sound signal, the volume control of the receiver was adjusted so that fully-modulated

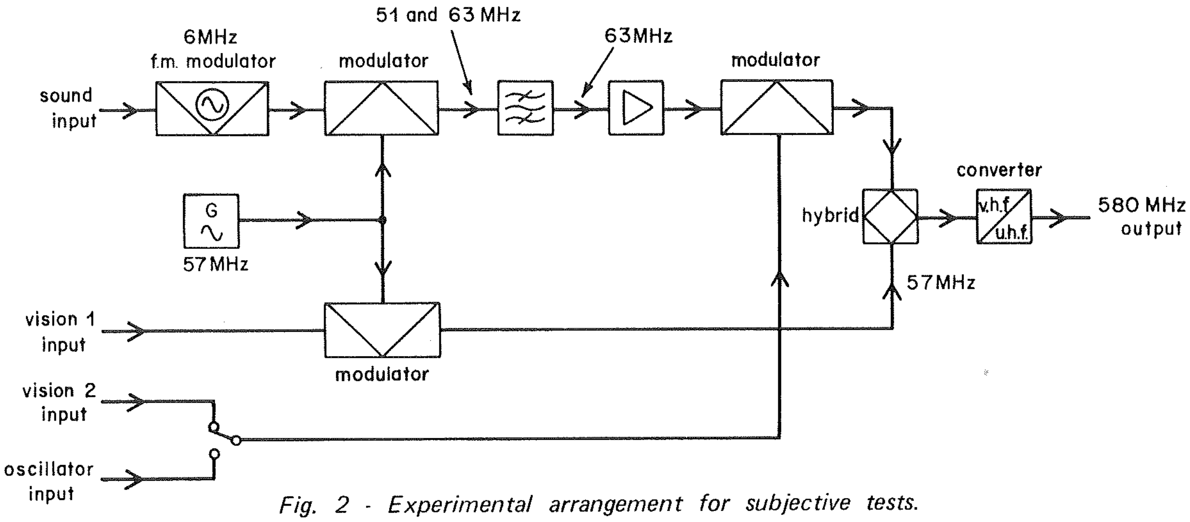

Fig. 2 - Experimental arrangement for subjective tests. Block diagram

speech was comfortably loud. The assessment of spurious noise was then made with the speech removed.

5.2. Results of tests

5.2.1. Relative importance of sound and vision effects

If the sound carrier is amplitude-modulated by the vision signal, it will have sidebands extending into the vision spectrum, resulting in an interfering pattern on the picture. Although this effect was not the primary concern of the investigation, it was considered appropriate to make some assessment of vision effects. Thus, the first test was a measurement of the amplitude variation required to produce a just perceptible pattern on the picture, and that required for a just perceptible buzz on the sound. The same video signal was applied to the vision carrier and to the sound carrier, to simulate cross-modulation. Two pictures were used, viz., full amplitude 75% saturated colour bars, and Test Card F. In most cases, the assessment of the sound buzz was made somewhat difficult by the presence of a significant amount generated in the receiver itself.

The results are summarised in Table 1.

These tests suggest that the effect on the picture is more important than the effect on the sound. However, the results were influenced by the occurrence of a relatively large amount of buzz introduced in the receiver, and they do not allow for possible improvements in receiver design in the future. Further tests were therefore carried out, as described below.

5.2.2. Critical tests for sound impairment

In order to assess the most stringent requirements as far as sound impairment is concerned, the cross-modulation generated in the reciever was reduced by using a line sawtooth waveform with no colour sub-carrier for the vision modulation. The sound carrier was then modulated by a square wave with a fundamental frequency of about 1 kHz.

In this test the interference was just perceptible on all the receivers when the amplitude variation was 3 to 5%. This is a critical test of the sound system, and this form of modulation is unlikely to arise frequently in practice. An approach to this condition occurs when the picture consists of horizontal black and white bars. A test was carried

TABLE 1

Percentage amplitude variation of sound carrier required to produce just perceptible impairment of vision and sound

Receiver	Percent amplitude variation of sound carrier			
	Vision		Sound	
	Colour bars	Test Card F	Colour bars	Test Card F
A	5	13	5	18
B	3	9	43	43
C	7	10	19	67
D	3	12	20	37
E	3	8	24	24

out in which the sound carrier was amplitude-modulated by a picture consisting of fifteen black and fifteen white horizontal stripes. The vision modulation was again a line sawtooth waveform. The test was confined to only two receivers, viz., A and C. The amplitude variation required for just perceptible interference was 7% and 6% respectively.

5.2.3. Average sound impairment with a variety of pictures

The tests described so far involved specially selected conditions, chosen to highlight certain effects. In order to assist in forming a judgement of the overall perspective of the problem, a final test was carried out in which the sound carrier was amplitude-modulated by a moving picture obtained from a high-grade 'off-air' receiver. The maximum amplitude variation was adjusted to be 10%. The vision modulation was again a sawtooth waveform. The test was carried out on receiver D.

Careful listening to the sound for about ten minutes revealed no significant effect caused by the sound amplitude variation.

6. Conclusions

If it can be assumed that the sound channel of a u.h.f. television receiver has an amplitude suppression ratio of at least 30 dB, it is considered that a 10% variation in the sound carrier amplitude, caused by cross-modulation with the vision signal, will produce little impairment of the sound programme.

Subjective tests carried out with some typical domestic receivers indicate that amplitude variations of less than 5% can, under some conditions, produce just perceptible impairment.

Existing relay stations employing klystron output stages introduce an amplitude variation of up to 7%, so that some viewers may suffer a slight degradation in the sound quality. It is, however, likely that the effect of this is masked by larger degradations introduced by the receiver.

The figures quoted above apply to the overall performance up to the receiver input, and if several sources of non-linearity, such as u.h.f. transposers, are connected in tandem, the specification of each component part must be more stringent.

The investigation described was necessarily very brief, and a more thorough study is required to provide a firm basis for a specification. Careful consideration must be given to possible impairment of the sound signal as well as the picture, when specifying cross-modulation performance.

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